Rectangular Duct: Friction, Nusselt Number and Wall Heating

Hydraulic diameter, Reynolds number, friction factor, Nusselt number, NTU, outlet temperature and pressure drop for flow in a rectangular duct with heated walls.

Input parameters

Unit system: SI

Parameter	Value	Unit
Long side of the duct	70.710	mm
Short side of the duct	70.710	mm
Duct length	5.0000	m
Mass flow	180.00	kg/h
Density	1.0463	kg/m³
Viscosity	0.020250	mPa·s
Thermal conductivity	0.029100	W/(m·K)
Specific heat	1.0080	kJ/(kg·K)
Inlet temperature	27.000	°C
Wall temperature	100.00	°C

Calculated results

Parameter	Value	Unit
Aspect ratio 2b/2a	1.0000	
Hydraulic diameter	70.710	mm
Mass flux	10.000	kg/(m²·s)
Reynolds number	34,919	
Laminar fully developed f·Re (Fanning)	14.230	
Laminar Nusselt number, constant wall temperature	2.9787	
Laminar Nusselt number, constant axial heat flux	3.6102	
Fanning friction factor used	0.005642	
Nusselt number used	89.755	
Heat transfer coefficient	36.938	W/(m²·K)
Number of transfer units hA/(ṁc_p)	1.0365	
Effectiveness 1 − e^(−NTU)	64.529	%
Heat transfer rate	2.3742	kW
Outlet temperature	74.106	°C
Frictional pressure drop	76.260	Pa

Notes for this case

- Turbulent: f = 0.0791 Re^−0.25 (1.0875 − 0.1125 α*) and Nu = 0.024 Re^0.8 Pr^0.4.
- Constant wall temperature with the fluid as the only resistance (C* = 0, ε = 1 − e^(−NTU)); properties taken constant.

Formula and method

$$D_h = \frac{4ab}{a+b}, \quad fRe = 24\left(1 - 1.3553\alpha^* + 1.9467\alpha^{*2} - 1.7012\alpha^{*3} + 0.9564\alpha^{*4} - 0.2537\alpha^{*5}\right)$$

$$Nu_T = 7.541\left(1 - 2.610\alpha^* + 4.970\alpha^{*2} - 5.119\alpha^{*3} + 2.702\alpha^{*4} - 0.548\alpha^{*5}\right), \quad \varepsilon = 1 - e^{-NTU}, \quad \Delta p = \frac{4fLG^2}{2\rho D_h}$$

Variables

$2a$	Long side of the duct	m
$2b$	Short side of the duct	m
L	Duct length	m
$\dot{m}$	Mass flow	kg/s
ρ	Density	kg/m³
μ	Viscosity	Pa·s
k	Thermal conductivity	W/(m·K)
c_p	Specific heat	J/(kg·K)
T_i	Inlet temperature	K
T_w	Wall temperature	K
α^*	Aspect ratio 2b/2a	-
D_h	Hydraulic diameter	m
G	Mass flux	kg/(m²·s)
Re	Reynolds number	-
fRe	Laminar fully developed f·Re (Fanning)	-
Nu_T	Laminar Nusselt number, constant wall temperature	-
Nu_{H1}	Laminar Nusselt number, constant axial heat flux	-
f	Fanning friction factor used	-
Nu	Nusselt number used	-
h	Heat transfer coefficient	W/(m²·K)
NTU	Number of transfer units hA/(ṁc_p)	-
ε	Effectiveness 1 − e^(−NTU)	-
q	Heat transfer rate	W
T_o	Outlet temperature	K
Δp	Frictional pressure drop	Pa

Method and standards

Laminar fully developed fits by Shah and London and turbulent rectangular-duct correlations, with the ε–NTU relation for C* = 0.

Assumptions and limits

- Smooth ducts, constant properties, no entrance effects.

Report details

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Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

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Reopens the calculator with the inputs of this report.